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Glacial Till Prospecting in Southwest Ohio: Implications for Improved Sampling

Dylan J. McKevitt
Cedarville University, dylanmckevitt@cedarville.edu

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Dylan J. McKevitt, Department of Science and Mathematics, Cedarville University, Cedarville, OH 45314, dylanmckevitt@cedarville.edu

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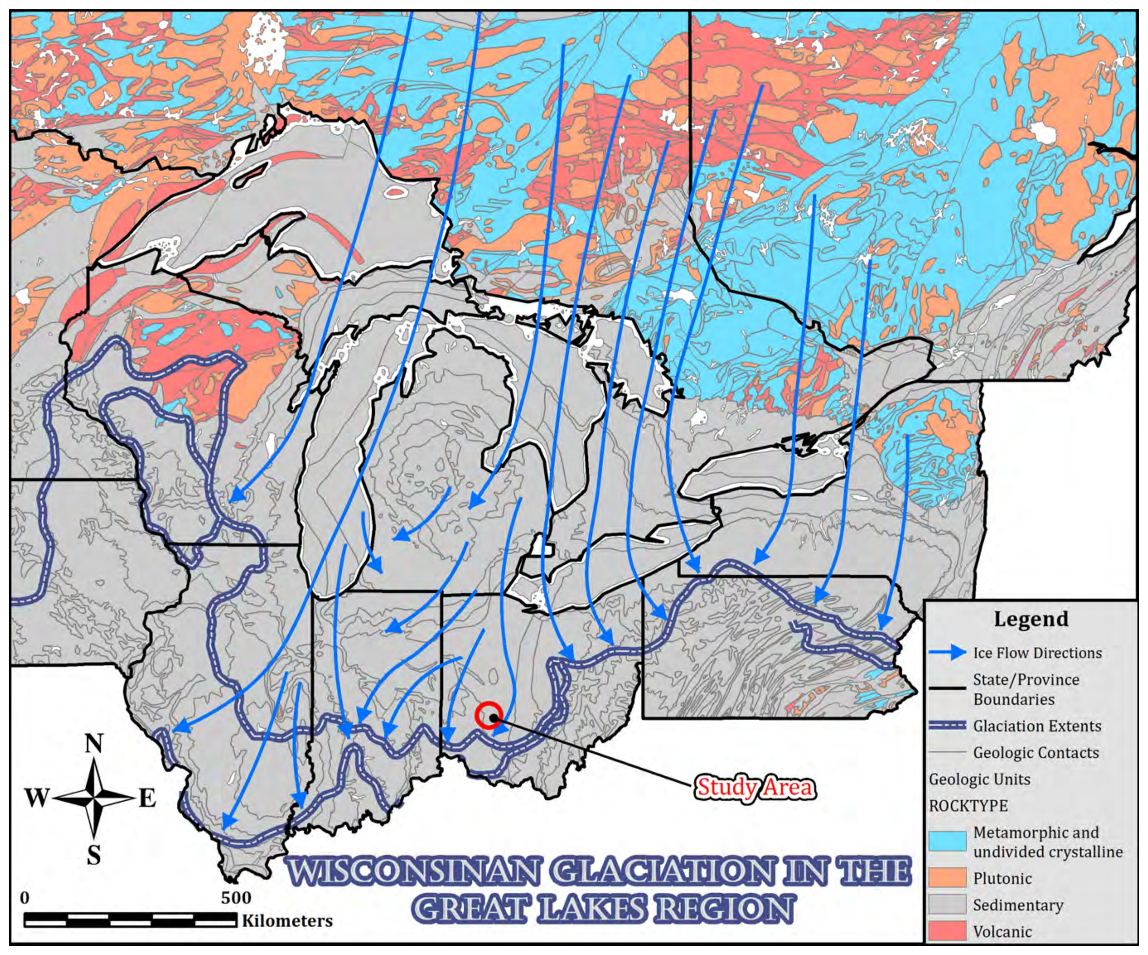
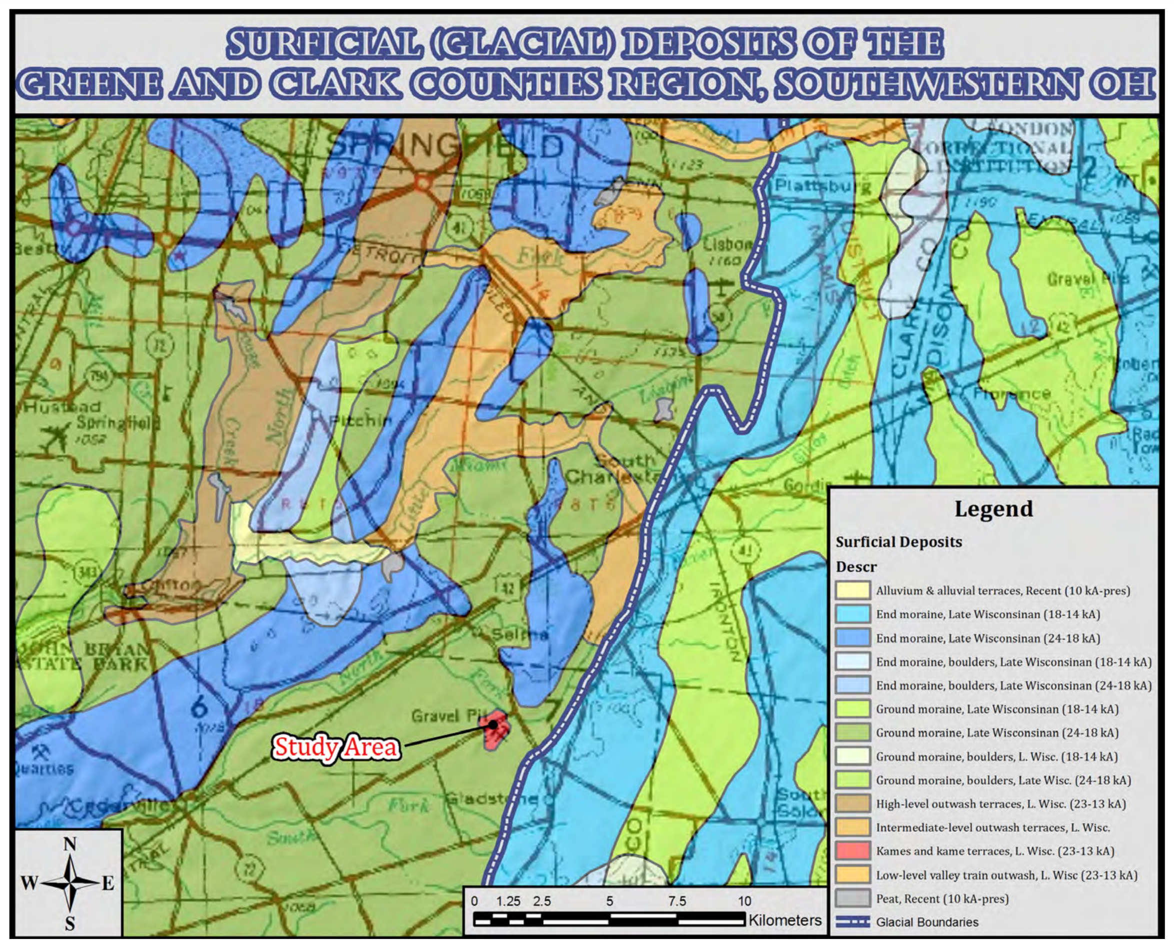
Abstract

Glacial till (drift) prospecting has served a major role in corporate mineral exploration, especially for gold and diamond during the past 30 years. It involves analyzing heavy indicator minerals from bulk sampling of various glacial deposits in order to track up ice flow direction to the potential orebody (such as a kimberlite pipe or Cu-Ni deposit), a technique commonly used in Canada but not in the U.S. Heavy minerals including diamond, gold, and native copper have been found in Ohio glacial till; the provenance of these heavy minerals is the Precambrian bedrock north of Ohio. This study utilized standard procedures in sample collection and analysis (sieving, concentration by gold-panning, heavy liquid separation with lithium metatungstate [LMT], magnetic separation and microscopy) with seven samples from a kame of the Late Wisconsinan glaciation in northeastern Greene County, southwest Ohio. Coarse to very coarse sand (2 - 0.5 mm) and fine to medium sand (0.5 - 0.125 mm) fractions from each bulk sample were analyzed for heavy minerals and felsic (quartz and feldspars) concentration. The goal was to determine variability in heavy minerals and felsic component concentrations across samples and between grain-size fractions, in order to suggest improved sampling and analysis techniques.

A variety of heavy minerals, including gold, of igneous and metamorphic provenance were identified in all sample fractions by physical and optical (including fluorescence) properties. Zircon concentration in the fine to medium sand fraction appeared similar across concentrated samples. Statistical analysis showed: significant variation of the coarser to finer grain size ratio between samples, displaying the expected variability in sand sizes in a kame deposit; significant differences in the felsic concentration within each grain size fraction across samples and between size fractions within samples. Taken together, results suggest glacial kame deposits can be useful repositories of heavy indicator minerals, yet due to sediment variability extensive sampling is required if kame deposits are to be used as benchmarks in till prospecting en route to an orebody.

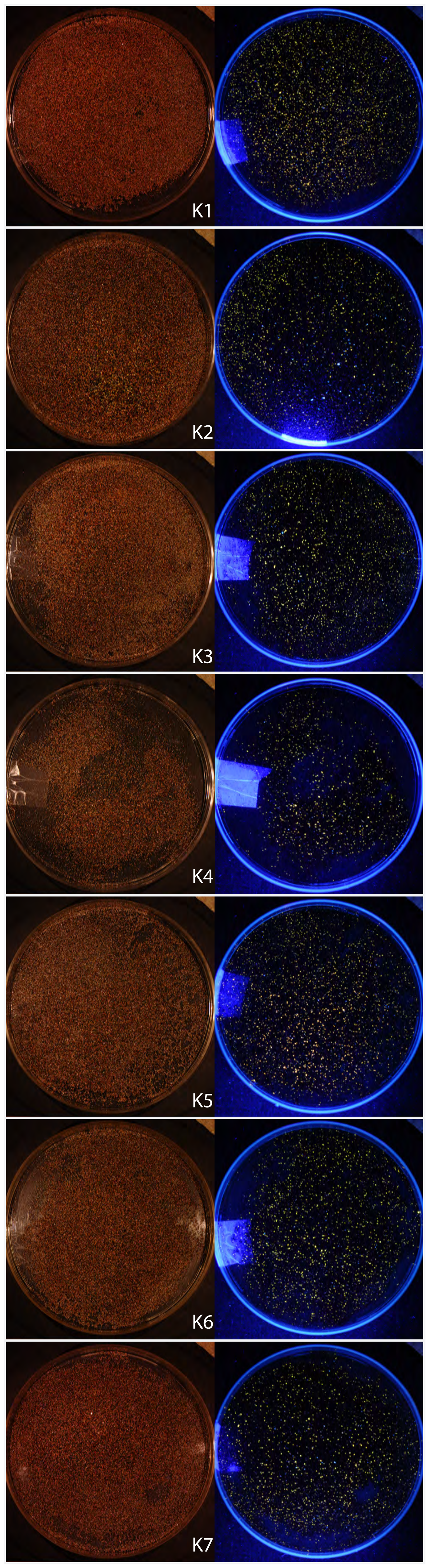




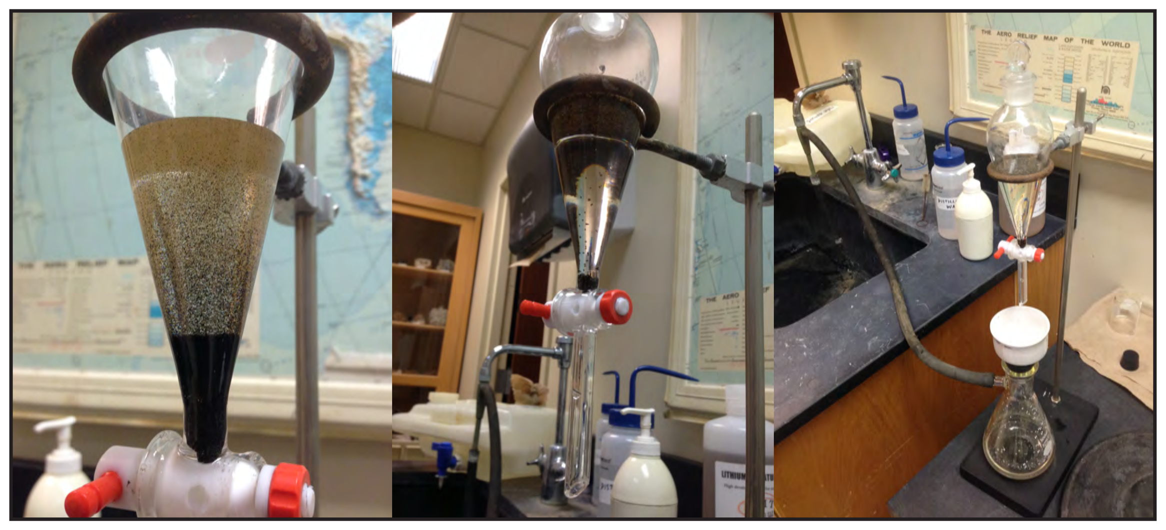
Regional Setting

Samples were collected from a glacial kame of the Late Wisconsinan glaciation (23 to 13 kA) located in northeastern Greene County, southwest Ohio (see maps). This glacial deposit lies near the distal end of the most recent glacial advance, and contains an assortment of material scraped from Ohio sedimentary and Canadian metamorphic / igneous bedrock, along with re-worked glacial till from earlier advances. Previous studies of till in southwest Ohio have noted heavy indicator minerals (including diamond and gold) originating in Canada.

Figure 4. Sieve size 35-120 samples of sink fractions displayed under normal and shortwave UV light. The orange fluorescent grains are zircons. Note the similar zircon concentrations. Petri dishes are 9 cm in diamter.



Methods and Materials



Sampling and analysis of material was conducted (with slight modifications) after the standard guidelines used by Canadian geologists. Seven 2.5-gallon glacial kame (gravelly sand) samples (K1-K7), spaced 5-10 meters apart, were collected from differing heights along a gravel-pit bank. These bulk samples were wet-sieved to separate out the sieve size 10-35 (2 – 0.5 mm) and mesh 35-120 (0.5 - 0.125 mm) fractions, which were then dried and massed.

Approximately 5 mL samples of each grain size fraction from each site were massed and separated into a sink and float fraction by standard heavy liquid separation techniques (Fig. 1), using lithium metatungstate (LMT) of 2.74 to 2.75 specific gravity. The float fraction included quartz and feldspars (felsics), along with lighter calcite/limestone grains which were subsequently completely dissolved with 3.0 molar HCl solution. After extracting magnetic grains with a rare-earth magnet, the resulting float (felsic) fraction was massed.

The remaining "bulk" sample fractions were each gold-panned to less than 5 mL. These concentrates were separated into float and sink fractions by heavy liquid separation with LMT of 2.95 (stock) specific gravity. The sieve size 10-35 sink fractions were analyzed and photographed using a Motic BA300 Polarizing Microscope and Helicon Focus 6 image stacking software (Fig. 2 and Table 1). The sieve size 35-120 sink fractions were photographed with a Nikon D5000 camera under plain and fluorescent light (Figs. 3,4 and Table 1).

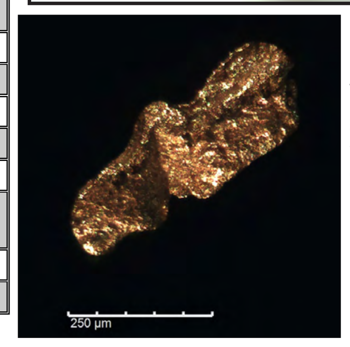
Appropriate statistical tests using R statistical software were conducted on the bulk and 5 mL sample fractions.

Figure 1 . Heavy liquid separation setup, featuring separatory funnel, Buchner flask, and filter funnel and paper. LMT, an inorganic heavy liquid, is diluted with distilled water which can be evaporated off later for recycling of the LMT. Note the sink, suspension, and float fractions. The finer the grain size, the longer the settling time.

Figure 2. Photomicrographs of selected grains from sieve size 10-35 (coarse to very coarse sand) sink fractions from samples K1 - K7. K1m and K7m are magnetic grains. Note the variety of heavy indicator mineral grains (see Table 1 for identification). Also note the abundance of spherical to hemispherical iron-oxide concretions. Scale bars are 1 mm. Each photo features tens of images stacked with Helicon Focus 6 software.

Table 1. Important heavy mineral constituents of heavy mineral sands, some used as indicator minerals in glacial till prospecting, and of igneous and metamorphic provenance. Note the Descriptions useful for identification under both normal and UV light.

Mineral	S.G. (g/cm³)	Stability in Weathering	Stability in Diagenesis	Provenance (I = Igneous, M = Metamorphic)	Description (mag = magnetic, SW = short-wave fluorescence, LW = long-wave fluorescence)
Amphibole	3.02…3.50	Low	Low	I and M	Black, elongated grains, two distinct cleavages
Cassiterite	6.98…7.07	High		Felsic plutonic I, hydrothermal deposits	Brown, strong adamantine / sub-metallic luster, SW (weak yellow)
Chromite	4.43…5.09	Moderate	High	Mafic and ultramafic I	Possibly weakly mag, black opaque, octahedral crystals, similar to magnetite
Epidote	3.12…3.52	Moderate	Low	Mostly M, some I	Light green to nearly black in larger crystals, elongate grains
Garnet	3.59…4.32	Moderate	Moderate	Mostly M, some I	Varieties: almandine (pinkish, Fe-rich, maybe slightly mag), spessartine (yellowish), pyrope (dark red/purplish); isometric crystals, LW (orange-red) for spessartine & pyrope
Ilmenite	4.70…4.79			I and M, sometimes hydrothermal veins	Opaque black, crystals more tabular than magnetite, slightly mag, often alters to leucoxene (appears as light-colored oxidized coating)
Kyanite	3.53…3.65	High	Moderate	M, rarely I	Light blue, possibly white-yellow-gray, elongate/rectangular, good cleavage, SW & LW (very weak red, pale yellow-white-pinkish-orange)
Magnetite	5.17…5.20		High	I and M, hydrothermal veins.	Opaque black, isometric/equant grains, strongly mag
Monazite	5.00…5.30	High	High	I and M	Yellow-reddish-brown, usually very small, mostly rounded & slightly elongate, SW (orange)
Olivine	3.22…4.39	Low	Low	Mafic and ultramafic I, some M	Bright green, glassy luster, rare in sand
Rutile	4.23…5.50	High	High	I and M	Deep reddish-brown, intense adamantine luster, elongate grains
Staurolite	3.74…3.83	High	Moderate	M	Deep brownish red/orange, elongated, commonly associated with garnet
Topaz	3.49…3.57			Felsic I, M	Usually colorless, elongated, prismatic, striations possible, single good cleavage perpendicular to striations, SW (green-white), LW (orange-yellow)
Tourmaline	3.03…3.10	High	High	Granitic pegmatites, some M	Various colors, indistinct cleavage
Zircon	4.60…4.70	High	High	I and M	Light-colored to colorless, small grains, often euhedral, common in sand, SW (orange-yellow)



The lone gold grain recovered, from sample K7. Scale is 0.250 mm.

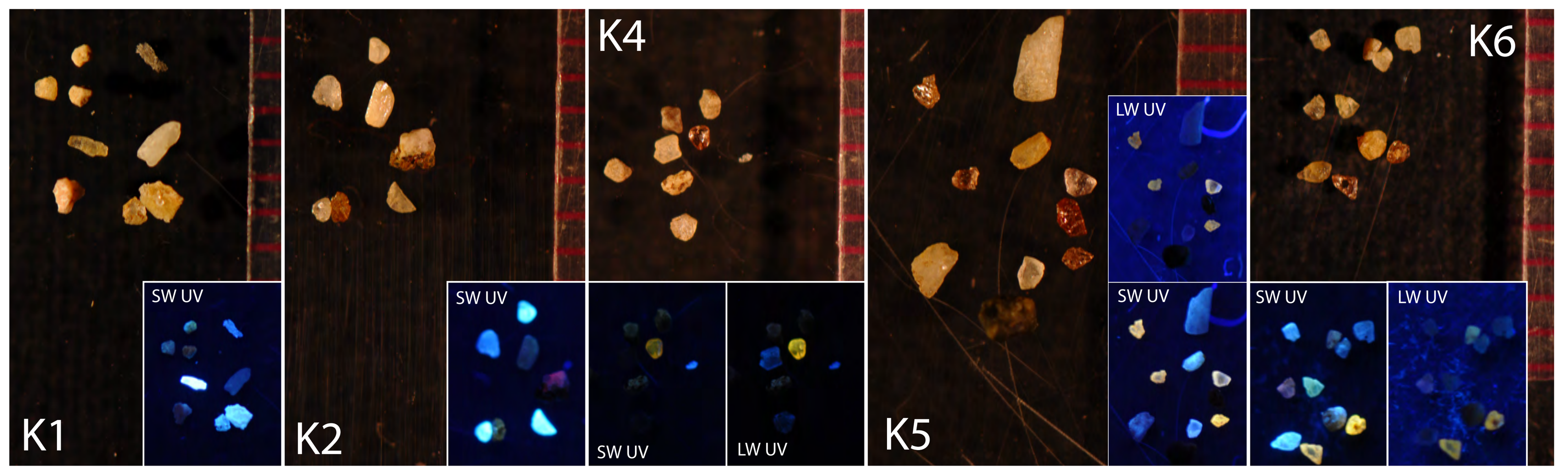
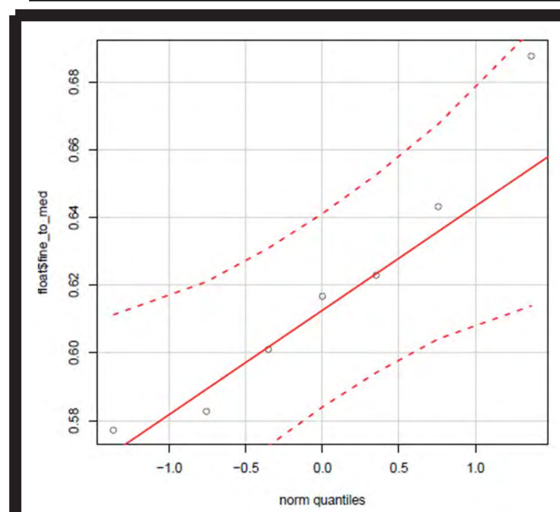


Figure 3. Selected fluorescent grains from sieve size 10-35 sink fractions. Inset images display short-wave ultraviolet light (SW UV) or long-wave ultraviolet light (LW UV). See Table 1 for mineral identification. 1 mm-spaced red tick marks on scales.



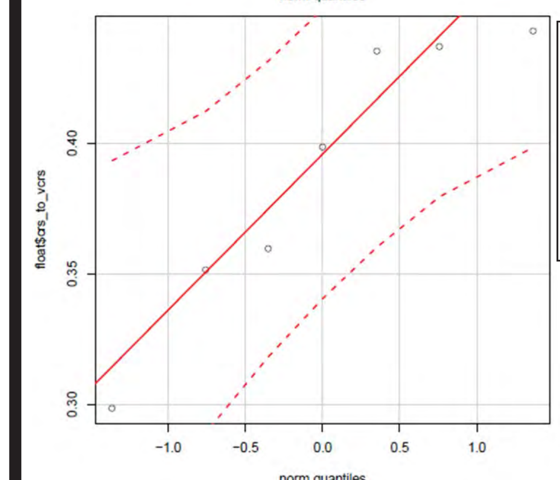

```
with(float, t.test(fine_to_med))

##
##  One Sample t-test
##
## data:  fine_to_med
## t = 42.91, df = 6, p-value = 1.072e-08
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  0.5836 0.6542
## sample estimates:
## mean of x
##    0.6189
```

```
with(float, t.test(crs_to_vcrs))

##
##  One Sample t-test
##
## data:  crs_to_vcrs
## t = 18.85, df = 6, p-value = 1.438e-06
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  0.3385 0.4395
## sample estimates:
## mean of x
##    0.389
```

One sample T-tests on sieve size 35-120 (fine_to_med) and sieve size 10-35 (crs_to_vcrs) float (felsic) fractions. The small P-values allows rejection (with 95% confidence) of the null hypotheses that the float/total mass ratios of 5 mL fractions from samples K1-K7 represent the true mean. Essentially, this means that any one measured felsic concentration (float/total mass ratio) will not accurately represent the overall deposit. Although the sample size was small (only seven), the Q-Q plots to the left show the data to be normally-distributed (with 95% confidence). Analysis done with R statistical software.



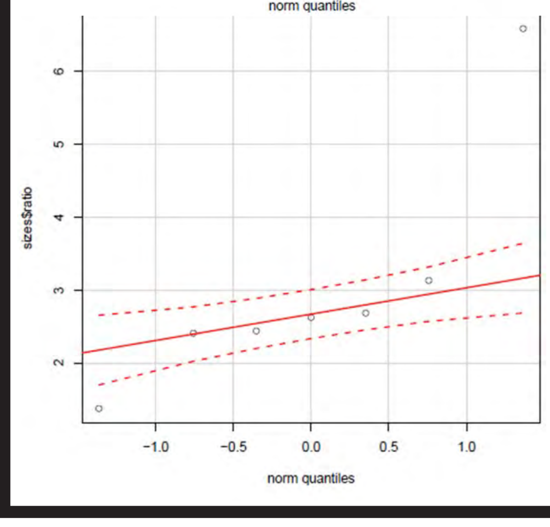

```
##
##  Paired t-test
##
## data:  fine_to_med and crs_to_vcrs
## t = 12.07, df = 6, p-value = 1.968e-05
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  0.1833 0.2765
## sample estimates:
## mean of the differences
##                 0.2299
```

A paired T-test and Wilcoxon rank sum test (for non-parametric / non-normal data) comparing the felsic concentration of the finer and coarser grain size fractions in each sample (K1-K7) to eachother shows (with 95 % confidence) that they differ significantly.

```
with(float, wilcox.test(fine_to_med, crs_to_vcrs))

##
##  Wilcoxon rank sum test
##
## data:  fine_to_med and crs_to_vcrs
## W = 49, p-value = 0.0005828
## alternative hypothesis: true location shift is not equal to 0
```

Statistical Analysis with R Statistical Software



The Q-Q plot to the left shows (with 95 % confidence) that the ratios of sieve size 10-35 to 35-120 for samples K1-K7 are non-normal. The Wilcoxon signed rank test (for non-normal data) below shows (with 95% confidence) that the grain-size ratio of any random sample from this kame will not accurately represent the overall kame deposit.

```
with(sizes, wilcox.test(ratio))

##
##  Wilcoxon signed rank test
##
## data:  ratio
## V = 28, p-value = 0.01563
## alternative hypothesis: true location is not equal to 0
```

Conclusions

The samples contained diverse heavy indicator minerals. Statistical analysis showed significant variation in grain sizes and felsic concentrations across the kame samples. This variability suggests that while kames may serve as repositories for heavy indicator minerals having traveled great distances, extensive sampling is necessary to obtain accurate, representative values of heavy mineral concentrations for tracing up-ice-flow to a potential ore deposit. Other types of glacial deposits may display less variability and facilitate less sampling and expense in mineral exploration; future studies like this one on other deposits in southwest Ohio are necessary.

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